(12) UK Patent Application (19) GB (11) 2 122 540 A

(21) Application No **8313848**
(22) Date of filing
19 May 1983
(30) Priority data
(31) **8214612**
(32) **19 May 1982**
(33) **United Kingdom (GB)**
(43) Application published
18 Jan 1984
(51) **INT CL³ B32B 3/12 3/10 3/24 5/08 // F01N 1/02**
(52) Domestic classification
B5N 0310 0312 0324 0508
F2X 7A 7G1 7K
U1S 1417 1987 B5N F2X
(56) Documents cited
GB 1420929
GB 1274871
GB 1237397
(58) Field of search
B5N
F2X

(71) Applicant
Short Brothers Limited
(United Kingdom)
PO Box 241
Airport Road
Belfast BT3 9DZ
(72) Inventor
William Norman Lavery
(74) Agent and/or Address for Service
Brewer and Son
5–9 Quality Court
Chancery Lane
London WC2A 1HT

(54) **Means for attenuating sound energy, and method of manufacture thereof**

(57) In an acoustic panel (10, Fig. 1), a facing sheet 33, 34 for a honeycomb core layer (12, Fig. 1) which has an imperforate backing sheet (11, Fig. 1), comprises an apertured layer 34 of fibre/resin composite material, preferably of an open weave to provide the apertures H, and a porous layer (33) face-to-face with the apertured layer with its pores P substantially smaller than the apertures H. One convenient way of making such a facing sheet is to cure the composite to shape on a tool with the porous layer in contact with it whereby the cured resin (R, Fig. 2) of the composite adheres the porous layer 33 to the apertured layer 34.

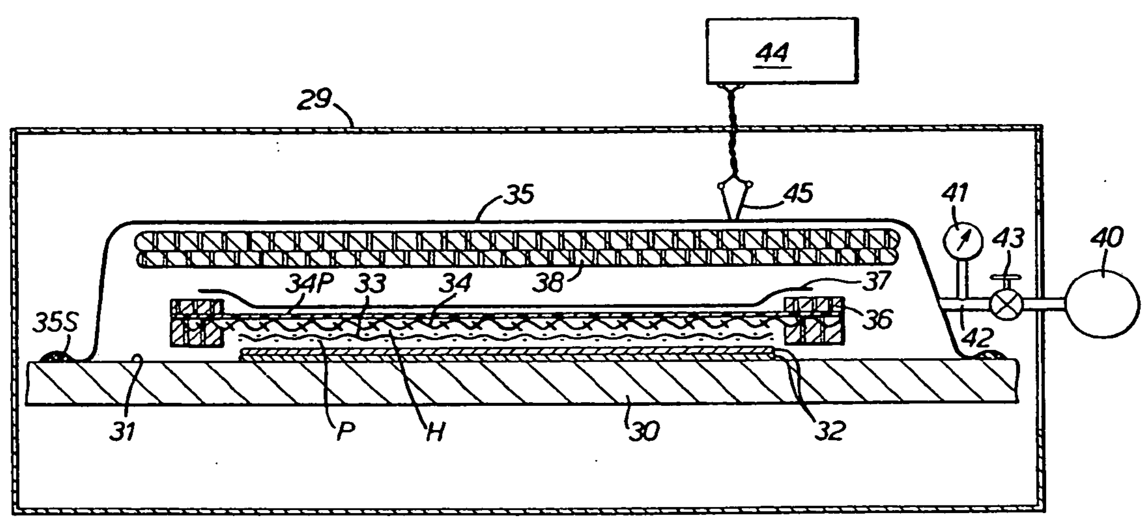

FIG. 3

GB 2 122 540 A

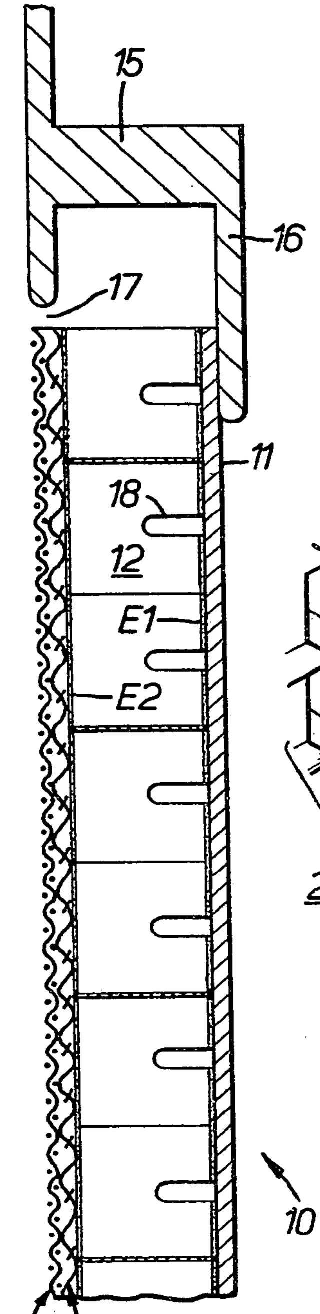

FIG. 1.

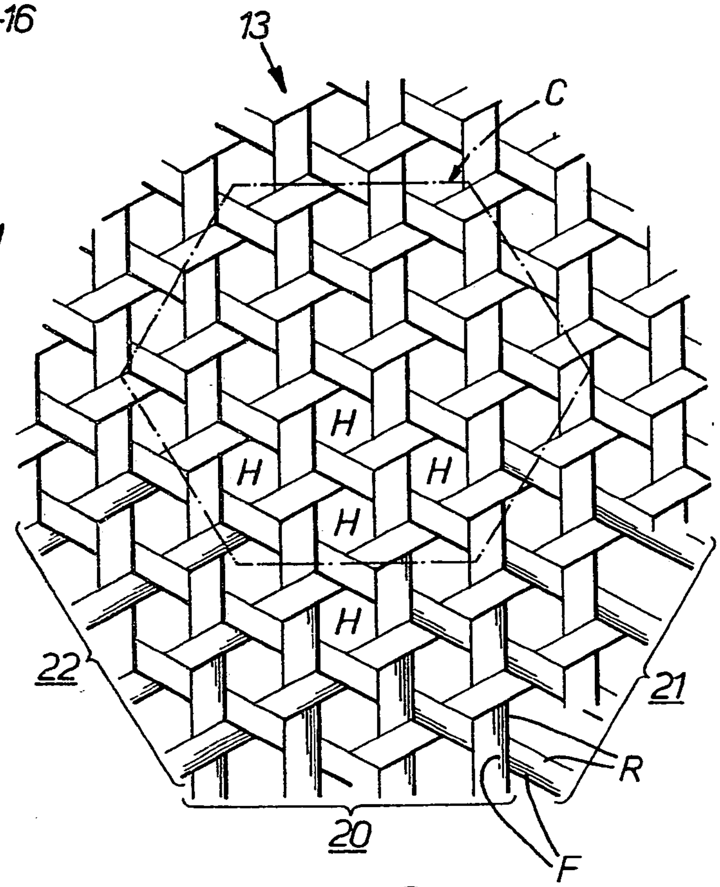

FIG. 2.

2122540

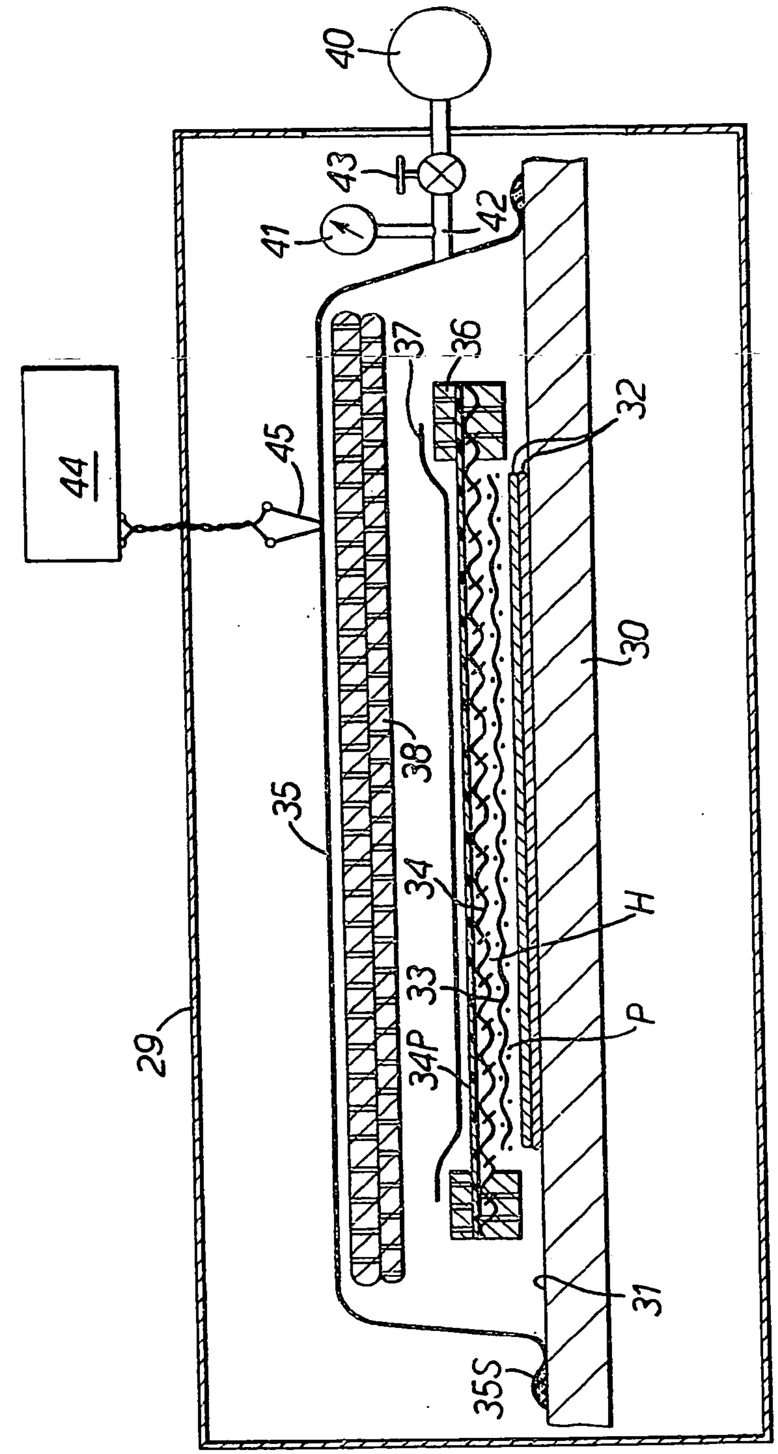

FIG.3

SPECIFICATION

Means for attenuating sound en rgy, and method of manufacture there f

This invention relates to means for attenuating sound energy, more especially but not exclusively noise attenuation panels (otherwise called acoustic panels), and to methods of making such means.

It has previously been proposed (see British Patent Application No. 2056367A) to use for attenuation of noise energy over a wide range of noise frequencies a so-called "linear" acoustic panel having a layer structure as follows:

i. an imperforate backing layer;

ii. an apertured layer, being a sheet which has been so manufactured that it has a multitude of through apertures, the apertures being of a predetermined and ordered size and spacing thereby to establish an open area characteristic of the layer;

iii. a cellular layer secured between the imperforate and apertured layers, a first end of all of the cells being covered by the imperforate layer and a second opposed end being closed by the apertured layer, a plurality of the apertures communicating with each of the cells which thereby constitutes a Helmholtz resonant cavity; and

iv. a porous layer adhered to the surface of the apertured layer opposite the surface to which the cellular layer is adhered and providing the external surface of the panel upon which air-borne noise is incident, the size of the pores of the porous layer being substantially smaller than the apertures in the apertured layer.

In such a panel, the honeycomb and the porous layer together provide the required wide range of noise attenuation and the apertured layer provides support for the other layers and is a structural member by which the panel is fastened to adjacent structure of the aircraft. Performance of the panel is impaired by any substantial change from a predetermined proportion of the surface area of the apertured layer which is open as between the porous layer and the cells of the cellular layer.

It is not easy to bond together the four layers of such a panel in such a way that, on the one hand, there is minimal likelihood of delamination of the panel in use and yet, on the other hand, a bonding step does not occlude so many of the perforations and/or pores that the characteristic open area of the apertured layer is lost and the efficiency of attenuation of sound is impaired. It is one aim of the present invention to ameliorate these difficulties.

It is another aim to provide a panel which is less heavy than equivalent prior art panels.

It is another object to provide a panel construction, and a method of assembly thereof, which facilitates construction of panels of complex shape.

According to a first aspect of the present invention there is provided a facing sheet for an acoustic panel, constituted by the apertured layer and the porous layer and characterised in that the apertured layer is formed from a fibre/resin matrix composite material.

According to a second aspect of the present invention there is provided a method of making a facing sheet for an acoustic panel characterised by the steps of:

i) providing an apertured layer formed from a fibre/resin matrix composite material which defines a multitude of through apertures of a predetermined and ordered size and spacing thereby to establish an open area characteristic of the layer;

ii) providing a porous layer the size of the pores therein being substantially smaller than that of the apertures in the apertured layer; and

iii) adhering the apertured layer and the porous layer together face-to-face to form the facing sheet.

A number of advantages stem from such use of a composite material, in place of the prior art material which is aluminium.

Firstly, the apertures can be formed while the resin matrix of the composite is in a part-cured condition. This is likely to be a far cheaper procedure than forming a like number of perforations in a metal sheet.

Secondly, the resin matrix of the composite could itself provide an adhesive medium by which the porous layer could be adhered to the apertured layer.

Thirdly, the fibrous component of the composite material could be arranged in a pattern, e.g. by weaving which in itself provides the required multitude of apertures, so removing any necessity for a separate aperture-forming step.

Fourthly, a particular problem with electrolytic corrosion is eliminated. One prior art panel has an apertured layer of aluminium and a porous layer composed of a stainless steel woven mesh or felt. Should these two layers be in electrical contact, electrolytic corrosion could occur in damp conditions. Prior art fabrication methods may include special steps to minimize the risk that in the finished assembly some part of the mesh or felt is in contact with the underlying apertured layer. A carbon fibre/epoxy resin composite material has substantially the same electrode potential as an overlying stainless steel porous layer, so the likelihood of electrolytic corrosion, and the need to take special steps during assembly to prevent contact between the porous lay r and the apertured layer, are both avoided.

It may be convenient to employ as a method of making a noise attenuation means in accordance with the invention a method

characterised by the step of securing the composite material layer to an adjacent one of said layers by holding the adjacent layer in contact with the composite material layer at a time when said resin is other than fully-cured and curing the resin with said two layers held in contact, whereby the resin secures the two layers together. The resin will probably be a so-called "controlled flow" resin, that is to say, a resin with a viscosity which is high enough that the resin remains jelly-like, during the early stages of its cure, rather than fully fluid. It may be convenient to provide a "peel-ply" layer, as described below, to absorb surplus resin.

In previously proposed panels, it is the apertured layer which is used to secure the panel to the adjacent supporting structure. In one embodiment of the present invention, the imperforate backing layer is so used. The present Applicants have noted that it is desirable to secure in the apertured layer a proportion of open apertured area, relative to the projected surface area of the layer, of around 30%. Such a high percentage of the surface area open, and a requirement to keep the panel as light as possible, detracts from the suitability of the apertured layer for mounting the panel to supporting structure.

An embodiment of the present invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a section through an edge region of a noise attenuating, acoustic panel, transverse to the plane of the panel;

Figure 2 is a plan view of part of the apertured layer of the panel of Fig.1, drawn to a larger scale and with the porous layer removed for clarity but with the outline included of one of the hexagonal cells of the underlying cellular layer; and

Figure 3 is a section through a facing sheet of the acoustic panel of Figs. 1 and 2 during manufacture thereof, with an associated forming tool and vacuum bag.

With reference to Fig. 1, the panel 10 comprises an imperforate, metallic backing layer 11 of aluminium alloy to which is secured by epoxy resin adhesive E1 a cellular honeycomb layer 12 in which each cell has at least one drainage slot 18. To the other end of the honeycomb cells is secured by epoxy adhesive E2 an apertured layer 13, described in more detail below. To the outside surface of the layer 13 is bonded a stainless steel mesh 14 of fine wire. The apertured layer 13 and mesh 14, taken together, are termed herein the facing sheet of the panel 10.

The panel 10 provides part of the inward-facing surface of a duct of a nose cowl for a turbo-fan aero engine, the panel being one of several arcuate panels disposed just upstr am of the fan of the engine. It is therefore of extreme importance that the panel does not deteriorate in use and, in particular, that no part of it becomes detached from its supporting structure. This structure comprises supporting flanges or stringers of which only one stringer 15 is shown. By bonding means known to those skilled in the art, the panel 10 is secured to the stringer, but it is to be noted that it is the backing sheet 11 of the panel, and not the apertured layer 13, which is secured to a panel-mounting flange 16 of the stringer 15. The gap 17 between the external surface of the panel 10 and the surrounding structure may be left open or could be sealed or closed for example by use of a mastic.

Referring now to Fig. 2, the apertured layer 13 is formed from a woven material of three sets, 20, 21 and 22, of threads each composed of a multitude of carbon fibres F. The three sets 20, 21 and 22 are arranged to be at 60° to one another so as to provide a multitude of apertures H of hexagonal shape. As can be seen from the superimposed outline C of one of the honeycomb cells of the cellular layer 12, there are a large number of apertures H for each one of the open ends of the cells C.

Uncured resin R surrounds the fibres F in the threads of the woven material but does not occlude the apertures H. During manufacture of the panel 10, the resin R is cured in an autoclave with the apertured layer 13 supported and arranged in the shape required in the finished panel, which may be a double curvature.

Providing (as a so-called "peel-ply") a layer of woven NYLON fabric on each side of the apertured layer 13 during the curing step will not only remove any "flash" of adhesive from within the apertures but will also apply the pattern of the weave to the surface of the sheet so that adhesive, subsequently applied, will key to it. Preferably, however, the outer layer 14 is held pressed into contact with the apertured layer 13 during the curing step, so that the resin serves to adhere together the two layers of the facing sheet of the panel 10.

One specific manner of carrying such a method into effect will now be described with reference to Fig. 3 of the drawings.

A former, herein referred to as a tool, 30 has a forming surface 31 which has the shape of part of the panel 10 is cleaned, conveniently using methyl ethyl ketone, and then receives two coats 32 of a mould release agent, such a Frekote 33 from Frekote Inc. of U.S.A., with a period of air drying between coats. The agent is then cured at 121°C for 30 minutes.

An area 33 of 720/150 (this designation indicates the number of wires per inch of fabric length, in warp and weft respectively) stainless steel mesh (such as that available from G. Bopp & Co. Ltd. of London N2, England under the designation "Robusta weave") sufficient to cover the working area

of the tool 30 is subjected to a vigorous vapour de-greasing treatment. It is then draped, using great care to avoid the introduction of wrinkles into the mesh, on to the tool 30 and is secured in position by tape (not shown) applied to its periphery. Where the tool 30 has a double curvature, slitting of the mesh is acceptable provided it is in positions laid down by design and production engineering specifications. It may be desirable to provide a film of a suitable adhesive around the periphery of the mesh and/or around any slit areas of the mesh in order to improve adhesion between it and the fibre/resin composite to be subsequently laid over the mesh.

The apertures P between the warp and weft strands of the mesh 33 constitute the pores of this porous layer.

Next, a sufficient area 34 of an open-weave carbon fibre fabric, such as is shown in Fig. 2, impregnated with a co-curing resin system, is carefully laid over the mesh 33. The fabric carries as a "peel-ply" a layer of NYLON fabric 34P on the surface of the carbon fibre fabric 34 opposite to the steel mesh 33.

Curing of the resin system is carried out under reduced pressure in an autoclave 29. The reduced pressure is secured by overlaying the tool 30 and layer structure 33, 34 thereon with a NYLON vacuum bagging membrane 35 in the manner shown in Fig. 3, and as now to be described.

Around the periphery of the fibre fabric 34 is provided a band 36 of a gas-permeable breather material, the band having a width of around 2–5 cms. A thin release film 37 suitable for use at elevated temperature is applied to the exposed surface of the uncured fibre fabric 34, to overlap the band 36 by about 1 to 1.5 cms. Overlying the release film 37 and band 36 is a breather sheet 38 of the same material as forms the band 36. The vacuum membrane 35 envelops the uncured workpiece and breather overlying it. Around the periphery of the membrane 35, where it meets the tool 30 is a sealing strip 35S of a high temperature mastic sealant.

Next, a test for leaks in the sealing of the vacuum membrane 35 and tool 30 is carried out by employing a vacuum pump 40 to reduce the pressure within the bag formed by the membrane to 55 cms. of mercury, as indicated, on a gauge 41, sealing the vacuum line 42 at a cock 43 and monitoring any pressure rise within the bag. A rise of not more than 12 cms. Hg in 5 minutes is acceptable.

Next, with the air within the bag still under reduced pressure, the autoclave cure is commenced. The ambient pressure in the autoclave and external of the bag is 3.1 ± 0.35 bar. When the pressure within the bag rises to

$$1.4 \pm {}^{0.69}_{0}$$

the bag is vented to atmosphere and, thereafter, it is maintained during the remainder of the curing treatment at

$$0 \pm {}^{0.35}_{0}$$

bar.

As to temperatures, these are controlled, by a temperature controller 44 which receives temperature data from a thermocouple 45 positioned adjacent to the workpiece, to limit the rate of temperature rise in the workpiece to a range of from 1 to 2.5°C/min., up to a curing temperature of 177 ± 5°C which is held for a period of

$$120 \pm {}^{60}_{0}$$

mins. Thereafter the workpiece is allowed to cool at a rate of 1.5°C/min. to below 60°C, the autoclave pressure is released and the workpiece removed from it.

As an alternative to slitting of the mesh 33, a complex shape of double curvature could be provided by weaving the mesh on a former of the required shape or by welding together at their peripheries a number of separate pieces of the mesh.

Other methods are envisaged. The apertures might be formed after weaving but before curing by moving the woven threads and restraining them in their new positions to provide the required apertures. The porous layer might be attached to the apertured layer after the latter has been cured to shape.

Referring to Fig. 1, an unapertured (but nevertheless usually woven) composite material for layer 13 might be cured to shape and only afterwards might the apertures be provided, possibly by perforating the layer 13, the outer layer 14 being attached subsequently. However, some of the benefits of the invention would not be gained by use of this procedure.

A sheet of the composite material could, while still uncured or part-cured, be perforated when flat, and then cured to shape in contact with the porous layer so as to bond thereto.

The cured facing sheet is then adhered to one face of the cellular layer 12, and an aluminium or fibre/resin composite backing layer 11 is adhered to the other face, both with an epoxy adhesive, as shown at E2 and E1 respectively in Fig. 1. Adherance of the facing sheet is assisted by the pattern of the weave of the peel-ply which remains on the

surface of the cured resin of the facing sheet. The cellular layer 12 can be NOMEX, a NYLON paper material, from CIBA-GEIGY (see hereinafter). The cell size is such that the largest circle which can be inscribed within each cell has a diameter of 9 mm.

The epoxy adhesives used were obtained from CIBA-GEIGY Plastics and Additives Co. Limited of Cambridge, England, and the triaxial weave, carbon fibre material from Barber-Colman Co. of Rockford, Illinois, U.S.A. Hexcel (U.K.) Limited of Lightwater, Surrey, England impregnate the fabric with their F593 controlled flow resin, and provide the impregnated fabric interleaved between sheets of polythene. The porous woven layer is from the British company, G. Bopp as aforesaid. As an alternative to the Bopp material there can be used the sintered stainless steel fibre mesh product sold as "BRUNSMET" by Brunswick Corporation of Dehand, Florida, U.S.A. Alternative woven carbon fibre materials are available from Brochier Industries of Villeurbanne, France.

Non-metallic porous layers are envisaged, e.g. woven meshes of a polyester material, and would have the advantage that they are of lower weight than an equivalent metal mesh. Adhesives and resins need not be of epoxy but could be, for example, a phenolic or polyimide resin. Carbon fibres could be replaced by other fibres provided they have sufficiently good mechanical properties. Glass fibres and KEVLAR are believed to offer performance inferior to carbon fibre for this application.

CLAIMS

1. A facing sheet for an acoustic panel, the sheet comprising:

i) an apertured layer, being a sheet which defines a multitude of through apertures of a predetermined and ordered size and spacing thereby to establish an open area characteristic of the layer; and

ii) a porous layer adhered to a surface of the apertured layer, the size of the pores therein being substantially smaller than that of the apertures in the apertured layer:

characterised in that the apertured layer is formed from a fibre/resin matrix composite material.

2. A facing sheet as claimed in claim 1 wherein the composite material is an open weave material in which the apertures are constituted by the openings between the threads of the weave.

3. A facing sheet as claimed in claim 2 wherein the woven material comprises three sets of threads mutually arranged at 60° to one another to provide apertures of hexagonal shape.

4. A facing sheet as claimed in any one of the pr ceding claims wherein the electrode pot ntials of the porous layer and the apertured layer ar substantially the same.

5. A facing sheet as claimed in claim 4 wherein the fibre of the composite material is of carbon and the porous layer is of stainless steel.

6. A method of making a facing sheet for an acoustic panel characterised by the steps of:

i) providing an apertured layer formed from a fibre/resin matrix composite material which defines a multitude of through apertures of a predetermined and ordered size and spacing thereby to establish an open area characteristic of the layer;

ii) providing a porous layer the size of the pores therein being substantially smaller than that of the apertures in the apertured layer; and

ii) adhering the apertured layer and the porous layer together face-to-face to form the facing sheet.

7. A method according to claim 6 characterised in that the step of adhering the apertured layer and the porous layer together and a step of curing the resin of the composite material are effected simultaneously with the resin acting as an adhesive between said porous layer and said apertured layer.

8. A method according to claim 6 characterised by the steps of shaping the apertured layer on a tool and curing the layer to shape on the tool prior to the step of adhering the apertured layer and porous layer together.

9. A method according to claim 6 or 8 characterised by the step of establishing said open area prior to completion of curing of the resin of the composite material.

10. A method according to claim 7 or 9 characterised in that the step of establishing said open area is a weaving step.

11. A method according to any one of claims 7, 9 or 10 characterised by the step of curing the resin of the composite material with at least one face of the apertured layer in contact with a peel-ply layer.

12. A method according to claim 11 characterised in that said at least one face is the face of the apertured layer which faces away from the porous layer in the cured facing sheet.

13. Means for attenuating sound energy comprising a facing sheet as claimed in claim 1.

14. Means for attenuating sound energy in the manufacture of which use is made of a method according to claim 6.

15. Means for attenuating sound energy as claimed in claim 13 or 14 which is a linear acoustic panel the backing layer of which is used to secure the panel to adjacent supporting structure.

Printed for Her Majesty's Stationery Office
by Burgess & Son (Abingdon) Ltd.—1984.
Published at The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.

THIS PAGE BLANK (USPTO)